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An Experimental Investigation on Strength Characteristics of Alkali Activated Fly Ash

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Abstract

Ordinary Portland cement and lime are often used as stabilising agent for weak soil improvement. However, a chief drawback allied with these stabilisers is that their production process asks for higher amount of energy and produces huge quantities of CO_2. Environmental threat, thus produced, is self-explanatory. Another intimidation to the environment is caused because of generation of enormous amount of fly ash from thermal power plants. Considering spatial and monetary limitations, disposal of such huge quantity of fly ash is a challenging aspect. Therefore, the present study attempts to improve the strength properties of fly ash by using alkali activation. Importance of the improvisation in strength of alkali activated fly ash can be realized by using it in soil stabilization purposes. The present investigation relies on a series of experiments conducted on fly ash in the laboratory to draw the conclusion that alkali activation in fact leads to enhanced strength of this waste and environmentally perilous material and also can render it as a construction material satisfying the required strength characteristics.

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*Keywords:*alkali activation; fly ash; NaOH; KOH;stabilisation

1. Introduction

A weak soil deposit lacks the required strength to support the loading of the civil engineering structures [1]. This type of deposit is often stabilised with Ordinary Portland cement (OPC) and lime. Attempts have also been made to stabilise such soils with geopolymers [2].However, the major drawback is that production process of OPC and lime is associated with high amount of energy consumption [2]. Estimated amount of CO_2 emitted from 1 ton cement production is about 1 ton [3]. On a different note, generation of enormous amount of fly ash from thermal power plants every year causes significant threat to the environment. Disposal problem is also a challenging issue in

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management of such huge amount of fly ash. Palomo et. al. (1998) conducted series of extensive laboratory testing for identification of the mechanism of activation of fly ash mixed with highly alkaline solutions. He further demonstrated that the temperature and type of activator are the considerable factors that affect the mechanical strength of fly ash [4]. Researchers also have attempted to activate the fly ash using alkalis of different silica contents and found that reaction products are dependent upon soluble silica content and reaction time [5].

Therefore, this paper attempts to establish alkali stabilized fly ash as a construction material as well as a replacement for weak soil in terms of its increased strength properties.

2. Materials and methodology

The fly ash used in this study is collected from NTPC, Angul. The specific gravity of fly ash sample is determined as per IS: 2720 (Part-III) and found to be 2.38 for as an average of triplet experimentation. Particle size distribution for the fly ash sample is obtained following the procedure described in IS: 2720- PART (IV). Figure 1 presents the particle size distribution (PSD) curve of the sample. Table 1 enumerates the physical properties and the related PSD characteristics of the sample inferred from the curve.

Standard NaOH and KOH pellets are used in this study. 2%, 4%, 8% and 12% of such alkalis are added to fly ash by total weight of the mixture and laboratory tests are conducted for heavy compaction and UCS test for strength assessment. Guidelines laid by IS 2720 (Part-VIII) and (Part-X) are followed for conducting the heavy compaction and unconfined compressive strength (UCS) test on the samples.

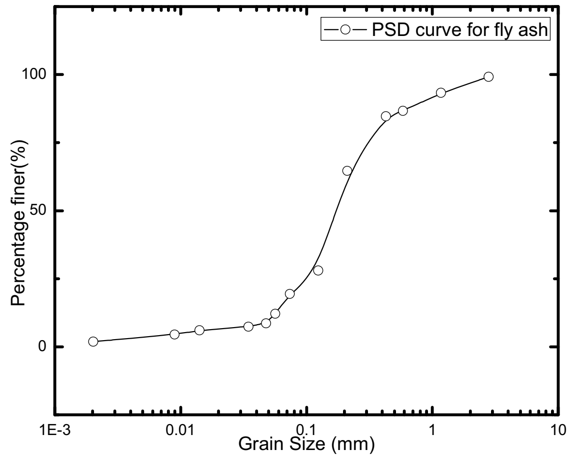


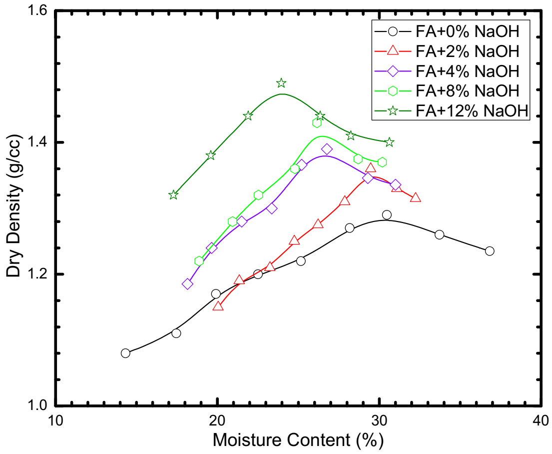
Fig. 1. Particle size distribution curve of fly ash

Table 1. Physical characteristics of the fly ash sample

Colour	Sand fraction	Silt and clay fraction	Coefficient of curvature, Cc	Coefficient of uniformity, Cu	Specific gravity
Light grey	12%	88%	1.25	5.67	2.38

3. Results and discussion

Figure 2 and figure 3 show the heavy compaction curves obtained for the fly ash sample stabilized with NaOH and KOH respectively. Furthermore, Table 2 presents experimentally obtained heavy compaction characteristics of the activated fly ash sample. It can readily be observed from Figure 3 that maximum dry density (MDD) of the activated fly ash increases with increase in alkali content. As the alkali content increases, a declination in optimum moisture content (OMC) of the samples is observed from Figure 4.



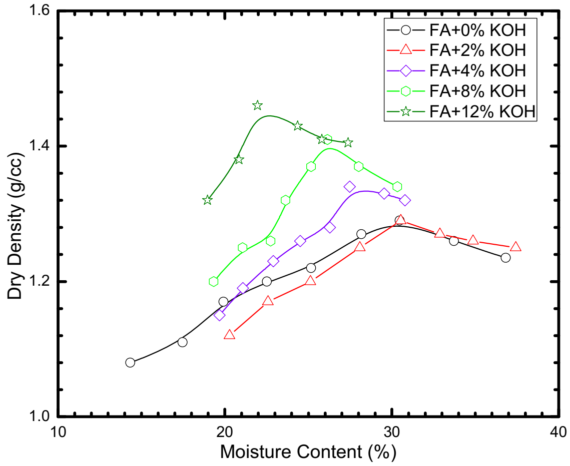
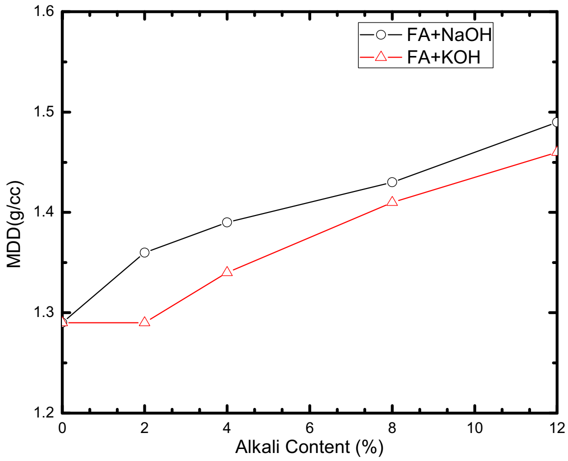


Fig.2.Heavy compaction test results for fly ash stabilized with NaOH Fig.3. Heavy compaction test results for fly ash stabilized with KOH

Table 2. Heavy compaction characteristics of alkali activated fly ash

Alkali Type	Alkali content(%)	MDD (gm/cc)	OMC (%)
NaOH	0%	1.29	30.33
	2%	1.36	29.47
	4%	1.39	26.77
	8%	1.43	26.15
	12%	1.49	23.95
KOH	0%	1.29	30.33
	2%	1.29	30.535
	4%	1.34	27.47
	8%	1.41	26.14
	12%	1.46	21.95



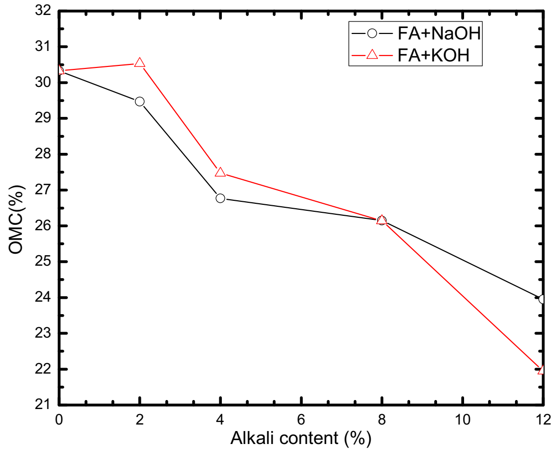
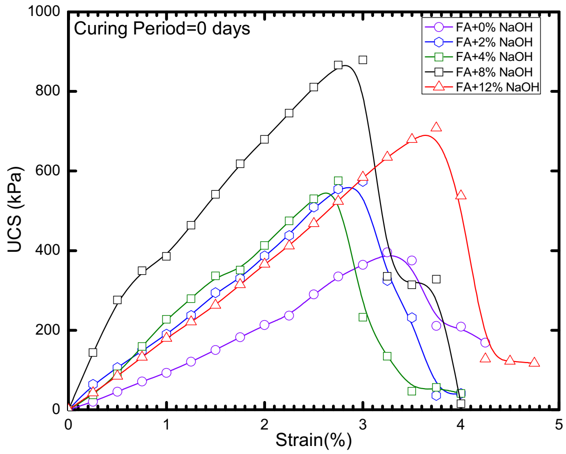


Fig.4. Variation of MDD of stabilized fly ash with alkali content

Fig.5. Variation of OMC of stabilized fly ash with alkali content



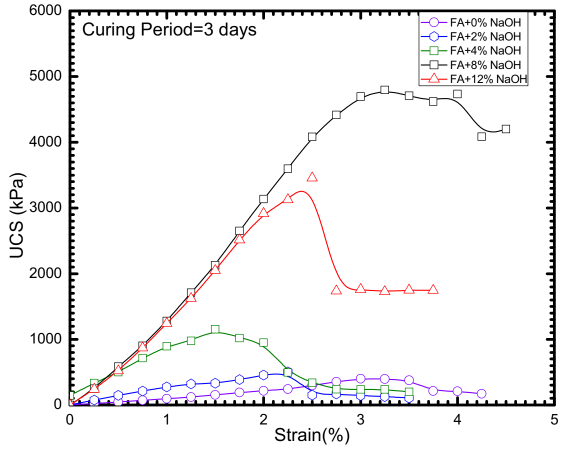
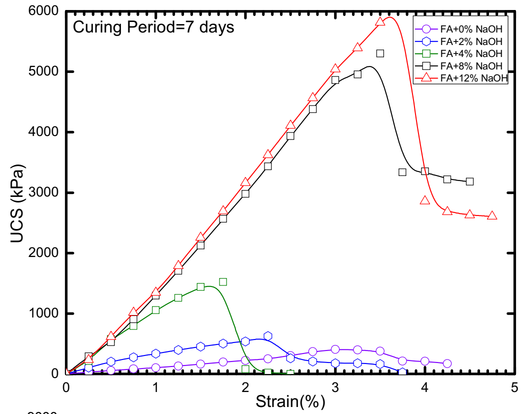


Fig.6(a) Fig.6(b)



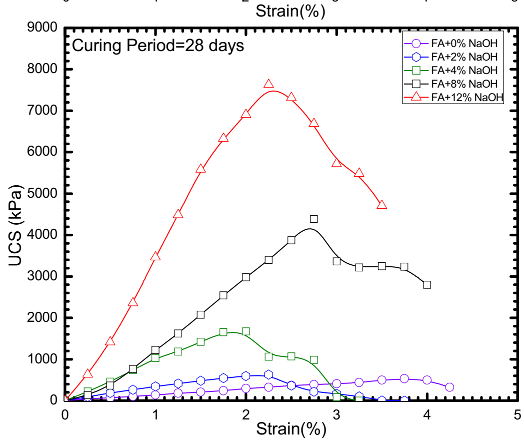
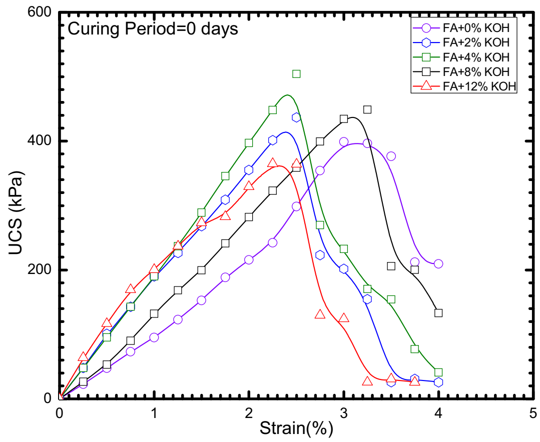


Fig.6(c) Fig.6(d)

Fig.6. UCS results for NaOH stabilized fly ash for different curing periods of (a) 0 days (b) 3 days (c) 7 days (d) 28days

Furthermore, figure 6. (a),(b),(c) and (d) depict the variation of UCS value of the NaOH activated fly ash over different curing periods. In a similar manner, figure 7. (a), (b), (c) and (d) show the variation of UCS value of the KOH activated fly ash over different curing periods. It is observed that, a general strength gain is occurring for the alkali activated fly ash with increase in curing period. However, an interesting variation is observed for addition of 8% of alkali. In such a case, UCS is increasing with curing period up to 7 days and a declination in strength is observed after 28 days curing.


Curing Period=0 days
FA+0% KOH
FA+2% KOH
FA+4% KOH
FA+8% KOH
FA+12% KOH
UCS (kPa)
Strain(%)
0
200
400
600
0
1
2
3
4
5

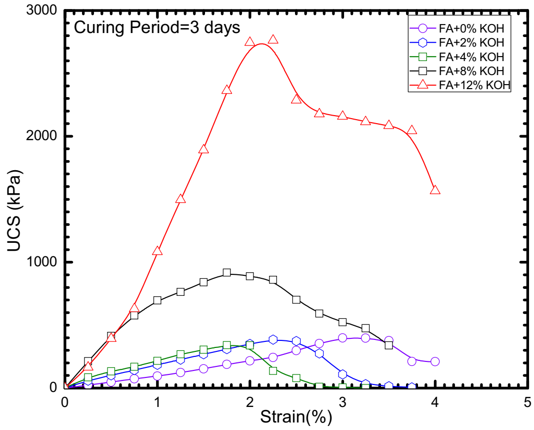
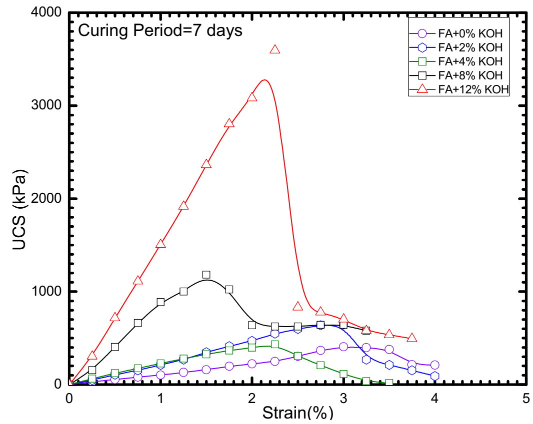

Curing Period=3 days
FA+0% KOH
FA+2% KOH
FA+4% KOH
FA+8% KOH
FA+12% KOH
UCS (kPa)
Strain(%)
0
1000
2000
3000
0
1
2
3
4
5

Fig.7(a)

Fig.7(b)


Curing Period=7 days
FA+0% KOH
FA+2% KOH
FA+4% KOH
FA+8% KOH
FA+12% KOH
UCS (kPa)
Strain(%)
0
1000
2000
3000
4000
0
1
2
3
4
5

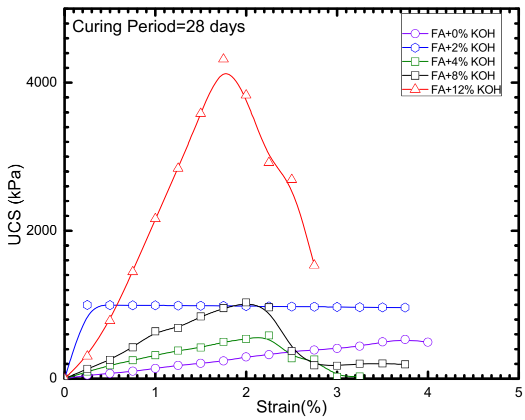


Fig.7(c) Fig.7(d)

Fig. 7. UCS results for KOH stabilized fly ash for different curing periods of (a) 0 days (b)3 days (c) 7 days (d) 28days

Figure 8 and figure 9 describe the variation of peak UCS over curing period for fly ash activated with NaOH and KOH respectively. It is observed that, for NaOH stabilized fly ash peak UCS obtained for 2%, 4%, 8% and 12% alkali addition are 630.75 kPa , 1672.37 kPa, 5300.56 kPa and 7630.026 kPa respectively. These strength values for NaOH activated fly ash correspond to 28 days of curing period. However, the peak strength for 8% alkali addition is observed after 7 days of curing. In a similar manner, for KOH stabilized fly ash peak UCS obtained for 2%, 4%, 8% and 12% alkali addition are 975 kPa , 583.84 kPa, 1181.88 kPa and 4318.497 kPa respectively. These strength values for KOH activated fly ash correspond to 28 days of curing period. However, the peak strength for 8% KOH addition is observed after 7 days of curing as the previous case. UCS value for unreinforced fly ash is found to 530.2kPa after 28 days of curing.

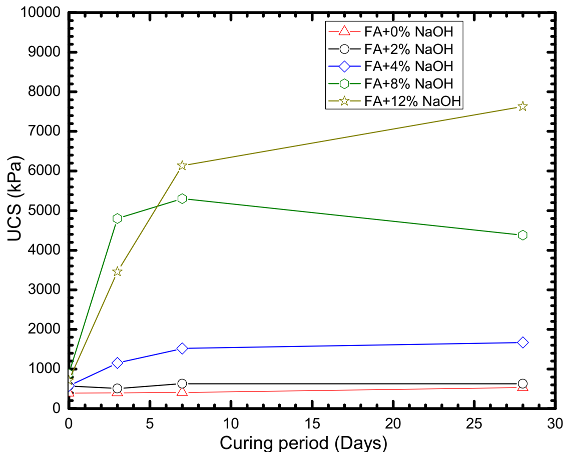


Fig. 8. Variation of peak UCS for NaOH activated fly ash over curing period

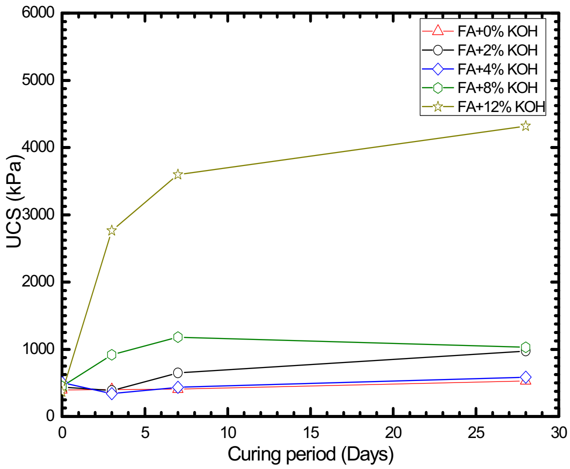


Fig. 9. Variation of peak UCS for KOH activated fly ash over curing period

4. Conclusions

The present study is devoted towards understanding the strength characteristics of alkali activated fly ash. Locally available fly ash sample is treated with several dosage of standard NaOH and KOH solution and tested for determination of strength parameters over extended curing periods. Heavy compaction results exhibit that, a reduction in the optimum moisture content and an increase of maximum dry density occurs when increased amount of alkali is used for stabilization of the sample. MDD values obtained for fly ash activated with 12% of NaOH and KOH are 1.49 g/cc and 1.46 g/cc respectively. OMC values observed for fly ash activated with 12% of NaOH and KOH are 23.95% and 21.95% respectively. OMC and MDD for unreinforced fly ash are found to be 1.29g/cc and 30.33% respectively. After 28 days of curing at room temperature of 27ºC about 7630 kPa and 4318 kPa of unconfined compressive strengths are obtained for fly ash stabilized with 12% NaOH and KOH respectively. For same amount of alkali addition, NaOH seems to deliver better strength to fly ash than KOH.

References

1. Barden L, Sides G. Sample disturbance in the investigation of clay structure.*Géotechnique* 1971;21(3):211–22.
2. Zhang et. al., Experimental feasibility study of geopolymer as the next-generation soil stabilizer, Construction and Building Materials 2013; 47:1468–1478
3. Khedari J, Watsanasathaporn P, Hirunlabh J. Development of fibre-based soil–cement block with low thermal conductivity. *Cem Concr Compos* 2005; 27(1):111–6.
4. Polomo et. al., Alkali-activated fly ashes: A cement for the future, *Cement and Concrete Research* 1999, 29:1323–1329
5. Criado et. al., An XRD study of the effect of the SiO_2/Na_2O ratio on the alkali activation of fly ash, *Cement and Concrete Research* 2007, 37: 671–679
6. Chowdhury et. al., Alkali activated fly ash: a new generation geo-material, *Proc. of 5th Ind. Young Geotechnical Engineers' conf.* (accepted)